POLICY FORUM: ECOLOGY

Biological Control of Invading Species—Risk and Reform

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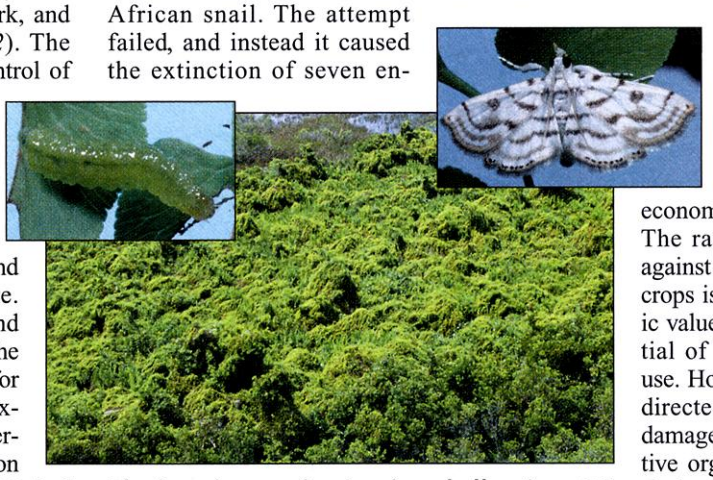
Biological control (BC), the science and technology of controlling pests with natural enemies, has had several recent successes, including suppression in Africa of invading mealybug and whitefly pests of cassava by means of introduced wasps (*1*). Increasingly, BC is used to suppress weeds in natural areas, such as the ecosystems of South African Cape Fynbos, the Australian Kakadu National Park, and the Florida Everglades, U.S.A. (*2*). The Everglades BC projects include control of the Old World climbing fern *Lygodium microphyllum* (see the figure). Biological control is also contemplated against insects invading natural areas and even against invasive marine species (*3*).

However, BC is not a panacea, and without careful use, it can misfire. Ecologists, conservation groups, and others have raised questions about the safety, rationale, and even the need for some projects (*4*). Safeguards to exclude importation of enemies dangerous to the native fauna are in place on very few borders of the world. In the United States, oversight of BC is based on a hodgepodge of old legislation meant for other purposes. Protection of native plants from foreign herbivores imported and disseminated for weed BC has been problematic; meanwhile, native insects and other invertebrates have little protection under the current structure. We suggest reforms that will reduce ecological risk and reinforce the public trust in this powerful technique.

Problems

Current problems derive from enemies introduced decades ago (*5*). For example, in 1957, the Argentine caterpillar *Cactoblastis cactorum* was introduced to the Caribbean without regard for the rich native *Opuntia* flora in nearby continental North America. It arrived, uninvited, in Florida in 1989; now *C. cactorum* attacks five native Florida *Opuntia* species, including the extremely rare semaphore cactus (*6*). Likewise, in 1968, evidence that the weevil *Rhinocyllus conicus* could feed on native North American thistles did not prevent its introduction from Europe (*7, 8*). Perhaps most egregious was the introduction in 1977 of the predatory, New World land snail *Euglandina rosea* to the Pacific Island of Moorea, to control the giant African snail. The attempt failed, and instead it caused the extinction of seven endemic species and, perhaps, the entire genus of *Partula* snails (*9*). There is also a long list of introduced parasitoid species, some of which cause high rates of mortality to native insects (*10, 11*).



The invasive species *L. microphyllum* is shown here (light green) blanketing Everglades tree islands in Loxahatchee National Wildlife Refuge in southern Florida. The insets show the adult and larval stages of an Australian moth *Cataclysta camptozonale* now being evaluated as a potential biological control of the fern.

Foreign organisms with considerable potential to harm native biota continue to be introduced into the United States. The BC campaign against the Russian wheat aphid introduced 29 new species of insect predators and parasitoids to 16 states between 1986 and 1993 (*12*). The ladybird beetle "seven-spot" (*Coccinella septempunctata*), is inferred to be the cause of the decline of native ladybirds over the midwestern United States, owing to competition with native species for food; it also eats ladybirds (*13*). Another example is the dissemination of the foreign black carp in industrial catfish ponds in Mississippi for suppression of pest snails. This fish poses great risks to the native diversity of mollusks in the Mississippi drainage (*14*). Broad diets make such foreign predators ecologically unsafe to import or disseminate.

Ecological Focus

In sum, BC is not a safe response to every pest, especially not to some native species perceived as pests. As native species are linked by trophic interactions to other natives and often have substantial ecological roles, they are the riskiest of targets for BC. The discontinued program against native rangeland grasshoppers illustrates these issues (*15*). Of a trillion native grasshoppers that contribute invaluably to the ecosystem, only a few species become abundant enough to be pests. However, a large fraction would have been harmed by the contemplated BC. Among the native species to be affected was the grasshopper *Hesperotettix viridis*, which feeds primarily on snakeweeds. Snakeweeds are poisonous native plants that cause great economic loss when eaten by cattle. The ratio of benefit to risk of BC against native insects that attack row crops is high because of the economic value of these crops and the potential of greatly reducing insecticide use. However, little research has been directed at understanding collateral damages to other native insects. Native organisms should be targets for BC only in exceptional circumstances and after study of collateral effects.

Importing multiple agents in a lottery search for one that might do the job increases the probability of attacks on native biota that are not the intended target (*16*). No obvious logical basis except importing the largest number of foreign enemies as quickly as possible was evident in the campaign against Russian wheat aphid. No apparent rationale for identifying the most useful species and, certainly, no species-by-species consideration of ecological risk versus benefit appear in the literature on this campaign (*13*, *17*). BC programs should focus on identifying the most useful species and avoiding the others.

Narrow diets of BC organisms are the mainstay of safety. In the case of stenophagous insects used for BC of weeds, risk of collateral attack increases for native species more closely related to the target (*9*). At the safest extreme are projects against weeds without close native relatives in the region. Good examples include the melastome *Miconia calvescens* invading Hawaii; musk thistle (*Carduus nutans*) in Argentina and Australia; and *Melaleuca quinquenervia* in Florida, U.S.A. (*18*). At

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the riskiest extreme are projects in areas with many native species closely related to the target weeds. Diets of BC agents in these projects need to be much narrower, so as not to threaten closely related natives. The relatively narrow diets of *R. conicus* and *C. cactorum* are not narrow enough to prevent damage to diverse native *Cirsium* and *Opuntia* flora in North America.

BC Regulation and Implementation

The greatest attention has been paid to safety when using BC for control of weeds. No U.S. law was created specifically for BC, but old statutes barring alien species harmful to agricultural plants have been applied to regulate importation of agents against weeds. Regulation is in the hands of the Animal and Plant Health Inspection Service (APHIS) of the Department of Agriculture, guided by the Plant Quarantine Act of 1912, the Federal Plant Pest Act (FPPA) of 1957, and the Noxious Weed Act of 1974. In recent years, more protection has been extended to native plants, consistent with the National Environmental Policy Act (NEPA) of 1970. Importation of new BC species for weed control begins with APHIS review of petitions to release the organism usually submitted by a scientist (representing a university, state, or federal agency), through the petitioner's state Department of Agriculture. Petitions are then reviewed by a Technical Advisory Group (TAG), with members representing different agencies of the federal government charged with control of weeds and protection of plants. If TAG recommends approval, APHIS then prepares an environmental assessment (an EA) per NEPA. If a finding of no significant impact is made, and if the U.S. Fish and Wildlife Service consulting on the EA concurs, a release permit is issued.

We suggest that a review process like this, with important changes toward openness and transparency, would be a good template for increased ecological safety of all BC. First, the entire record should be made public, perhaps by means of timely posting on the World Wide Web. Second, the TAG should be opened up to include experts representing the range of stakeholders; ecologists from academia and private-sector conservation organizations, as well as from government, should be represented. Third, we advocate external peer review of petitions. The government agency best suited to regulate BC, one serving the range of interests from conservation to agriculture, should be chosen after national discussion of these issues (*19*).

At present, APHIS has no clear authority to prevent importation of species that threaten nonagricultural animals (for example, insects, mites, and clams) unless these are construed as pests of plants. NEPA does not apply to state and other nonfederal activities. The result is that most native insects, mites, and other invertebrates lack the key combination of legal and regulatory protections afforded plants. Invertebrate species are crucial to biodiversity and the ecological integrity of our wild, urban, and agricultural landscapes. Herbivorous insects and mites control plants that could become pests in the absence of this natural control. Invertebrates control herbivores, both native and alien, that could severely harm vegetation. Indirect interactions among native invertebrates contribute additional glue to our natural communities (*17*).

The sensible course is to extend federal protection to minimize risk to all native organisms. Exceptions can be made for the small number of unequivocally serious native pests. All proposed introductions of herbivores and carnivores should meet criteria of need, appropriateness, predicted efficacy, and ecological safety. Data pertinent to safety should include the hosts or prey in the native region of the candidate, as well as results of host-prey specificity testing.

Finally, regulations should continue to apply to BC organisms after they are introduced and to restrict propagation and rerelease of those that damage nontarget organisms. APHIS influence usually ends when the permit for the initial release is issued to a state. Although APHIS has authority to revoke release permits of introduced agents, it is rarely, if ever, exercised. Once a BC organism is in the United States, the knowledge that it harms native species does not stop its dissemination by nonfederal groups.

Introduced natural enemies do not respect political boundaries. *C. cactorum* crossed the U.S. border into Florida after release in the Caribbean. Some of the most threatening invasive species are marine, such as the algae *Caulerpa taxifolia*, which is overrunning the benthos of the Mediterranean Sea, and the European green crab, *Carcinus maenas*, recently introduced to the Pacific coast of North America. BC is contemplated for the former with a tropical sea slug and for the latter with a castrating barnacle from Europe; both of these organisms could easily cross international borders after release (*3*).

Imported natural enemies are the last best hope to fight some of the most damaging exotic pests. Inappropriate BC introductions are a small but crucial part of the large problem with invasive species (*20*). In the absence of reform, opposition to biological control—rational as well as irrational—will grow. A few sensible steps such as those that we suggest herein will maintain public confidence and support for this powerful tool.

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